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A COMPARISON OF BODY TEMPERATURES OF LEAST WEASELS AND WOLVERIN--ETC(U)
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By

G. Edgar Folk, Jr., Mary A. Folk, and Derek Craighead

Department of Physiology and Biophysics

The University of Iowa, Iowa City, Iowa 52242

and

The Naval Arctic Research Laboratory

Barrow, Alaska 99723

Send correspondence to:

Dr. G. Edgar Folk, Jr.
Department of Physiology and Biophysics
The University of Iowa
Iowa City, Iowa 52242

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1. At Barrow, Alaska, the resting T_b of the least weasel (40g) is relatively low (36.6°C) compared to 38.0°C for the wolverine (15kg).
2. There is a daily spontaneous rise in wolverine T_b (2.0°) due to exercise and circadian body temperature setting.
3. The four wolverines studied here could be predicted to be hyperactive from 8 AM to 2 PM, and to have bouts of sleep between 8 PM to 8 AM.

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The wide range in size of species within the weasel family (from 35g to 18kg) makes a comparison of their body temperatures especially interesting. Also, weasels are excitable, rapid-moving and unusually alert; for this reason they could have a daily average body temperature which is higher than more sluggish species of mammals. In this paper we report the body temperatures at four times of the day, of 16 least weasels and four wolverines.

Methods

The animal material consisted of: 16 least weasels, Mustela rixosa eskimo (Stone), maintained at least two months in captivity, captured at Point Barrow in summer, mean weight 46g. They were fed ad libidum on live or dead mice. After two months, they could no longer be maintained in the colony at the Naval Arctic Research Laboratory. As a contribution to the ongoing research programs of three universities, the 16 weasels were sacrificed at four times of the day with the following distribution of materials: blood to H. Ferguson, organs to R. Andrews, T_b measurements by E. Folk.

The wolverines, Gulo luscus luscus (Linnaeus), (designated K,L,M,N) each approximately nine years old, had been

maintained for a number of years at the Naval Arctic Research Laboratory. Their sources were as follows: two males from Yukon Territory, trapped May, 1969 (M 13.4kg, N 13.4kg); two (one male, one female) from Hoor, Sweden, sub-adult in October, 1966 (L 14kg, K 17.8kg). These animals were maintained in large cages, 3.7m by 2.5m by 2.5m, segregated from camp by a restricted area. Prior to and during the study, a circular restricted area was marked by rope to keep personnel 20 meters from the cages. Further away from the cages, signs indicated that no one was to approach the restricted area during the period of the study. The wolverines were fed reindeer meat and bone ad libidum during the study.

The environment at the time of this experiment makes the daily rhythm of body temperatures especially interesting; all weasels and two of the wolverines were studied during the period of 82 days of continuous light. The other two wolverines were studied during a period of 82 days of continuous lack of sunlight. The mean air temperature at the cages during the summer experiment was 11°C, and during the winter, -22.7°C (wind 4.9mph).

The technique of recording temperatures differed with the two species. In the weasels, liver temperatures were measured in exsanguinated animals; in the wolverines, temperature radio-capsules were implanted. The weasel liver temperatures were taken by the Stop Heat Flow Technique described earlier (Folk and Grubb 1977). In this technique

organ temperatures are read to the nearest 0.01°C by needle probe within one minute after guillotining the animal. Earlier studies showed that after this exsanguination, mammals the size of weasels and small rodents provide organs which are essentially unchanged in temperature for approximately one and one-half minutes. If the temperature of the center of a kidney, liver, or rectum is taken by needle probe, at the first half-minute after sacrifice the temperature will usually be 0.04°C warmer than control temperature; at one minute, 0.02°C warmer, and at one and a half minutes, 0.04°C cooler. This assumes that the sacrifice of the animals is done at a room temperature of 22-23°C. Thus, when small mammals are guillotined, essentially their internal organs retain control body temperature for one and one-half minutes.

The wolverine body temperatures were taken by four implanted radio-capsules especially made by the Barrows Company, Woodside, California; these were pulse-modulated, long-life transmitters with a range of approximately 8m (size, 55mm long, 16mm wide, weight 35g). They were implanted and secured in each ventral abdominal cavity, one to two weeks before the first readings were taken. Their temperature coefficients were either 1.5 pulses/0.1°C or two pulses/0.1°C; these audible pulses were counted with the aid of a stop watch. The pulses could not be recorded automatically on paper because the Point Barrow region is electrically noisy, and filtering the signal is difficult.

Transmission was to a loop antenna around the inside of the animals' cages. An antenna wire 30m long continued from the loop to the observation building where the signal was heard on an Ark-5 receiver (kHz band).

The temperature transmitters from the Barrows Company are electrically stable and on several occasions have provided temperature information for two years without a change of battery. To illustrate their stability some calibrations at various dates were (in pulses/min):

T_A*	April 5	April 27	May 3	June 7
	pulses/min	p/m	p/m	p/m
22.5°C	87	88	88	88
22.8°C	89	89	89	--
23.0°C	90	91	91	91

* Transmitter at equilibrium with this air temperature.

One objective in collecting body temperatures over several days is to obtain the resting, or basal, or sleeping temperatures so that these values might be related to size of mammals. Samples of weasel temperatures were obtained for only one 24-hour period at 6 AM, noon, 6 PM, midnight and again at 6 AM; wolverine temperatures were taken at least every six hours for an eleven-day period.

Actograms were devised with the aid of field glasses, or by noting attenuation of the signal due to animal movement away from the loop antenna. The activity pattern of each animal could be influenced by three different conditions.

One of these is due to a low physiological setting which is apt to occur in most mammals approximately every 24 hours (Folk 1974, pp. 75-77). A second factor is the possibility of an Aschoff effect (Aschoff 1960) or a free-running effect on the animals being studied, because they were maintained in both continuous light or in continuous lack of sunlight. If the Aschoff effect were present, then a low point of body temperature or a peak of body temperature might come later each day until these times progress around the clock. The same applies to the peak of activity in the free-running condition. Details are explained in Folk (1974, p. 32).

There is a third possible influence upon the resting body temperature of the animal; the time of low point or peak might oscillate early or late from day to day. All three of these possibilities have been considered in analyzing the results in this study. By definition, it was decided at first to select the lowest mean body temperature at a particular time of day, for the purpose of describing the resting body temperatures of both species.

Results

The resting body temperature of the least weasel usually ranged from 36.2 to 36.9°C (Table 1). The lowest mean which could be considered a representative figure, is 36.3°C found at noon. For comparison the lowest values for each of the five times of day are averaged and once again the mean is 36.3°C. However, the selection of resting values should be based upon time-of-day. Most high values (probably

representing a high setting) fell at 6 PM and midnight. Therefore the average from 6 AM and noon (36.6°±.23 SE) is reported as the basal resting temperature of the least weasel in our experiment. This figure is similar to the average for all times of the day (36.92°±.21 SE). In this sample of 16 weasels, all but three were guillotined when they were found in a very quiet or sleeping condition. The remaining three were found at different times of the day in a hyperactive state, running about, climbing or biting the cage. These three could represent the body temperature condition of this species when running on the tundra in search of prey; their values were:

	T_b	Weight	Sex
	38.6°C	70.0g	M
	38.0	69.5	M
	38.1	52.0	F
Mean	38.2	63.8	

The body temperature of the wolverines were higher than those of the least weasels. The data for wolverine "Lotta" is presented in Table 2; the data for the other three wolverines has been deposited in the National Auxiliary Publications Service.* Note that at 6 AM and at 6 PM there was about a 1°C difference in mean body temperature. At the start of this series, readings were taken every 30 minutes in order to expose the resting baseline which extends throughout the day and night (Fig. 1). For example,

* 305 East 46th Street, New York, NY 10017

it was known that at point S2 on the graph the animal was sleeping at a high body temperature setting. It was pointed out on an earlier page, however, that basal resting temperatures would be defined as those obtained at the low body temperature setting (S1).

The data for all four wolverines were examined for evidence of the Aschoff effect in which the peak of temperature might progress systematically to a different hour each day. High values (H) for one animal for each day are indicated on Table 2; they all fall at noon or at 6 PM. If there were an important Aschoff effect such a pattern would not be possible. On the same chart, low values are indicated in brackets; all except one fell at 6 AM or at midnight. This again indicates that there was not an Aschoff effect. However, with peaks or valleys falling on two specific times of the day, it is possible that there is an oscillation of the low point of the daily temperature rhythm; therefore, two analyses were done. The lowest mean temperature for one time of the day was selected, and these all turned out to be at 6 AM for all four wolverines; the activity patterns of these animals appeared to be in phase. However, if an oscillation occurs it would be more accurate to average the lowest temperature of each day instead of selecting the temperatures at one time of the day. Therefore, in the summary Table (Table 3), both methods of analysis are presented as was done with the least weasels. In other words, the mean for 6 AM for each wolverine is presented and also

the mean of the lowest value each day for all days. As was the case with the weasels, the results were very similar, a value of 37.6°C for the 6 AM readings and 37.5°C for the average of the lowest daily body temperatures.

One of the wolverines (K) had a resting body temperature from 1.4°C to 2.1°C lower than the other wolverines. Three months after the experiment, the transmitter of this animal only, had changed its calibration. It read a body temperature 3°C lower than at the start. It may be that there was a calibration change of 1°C per month by this transmitter. Therefore the temperatures of wolverine K were not included in the final average, but were considered in the daily percent change and the effect of exercise.

We had an opportunity to compare the wolverine temperatures with that of a single arctic wolf, age 1 1/2 years, maintained in the same physical environment and in fact in a cage of the same size beside the wolverines. This female wolf had been "socialized" and a staff member of the Naval Arctic Research Laboratory, Kate Persons, took rectal temperatures when the animal was quiet and also after the animal had been running on the tundra. The wolf resting readings of 37.9°C are essentially the same as the wolverine readings of 37.6°C taken at the same time of day.

Discussion

The body temperature of the least weasels (36.6°C) was about one degree lower than that of the wolverines; the reverse might have been predicted because many large species have

relatively low body temperatures (donkey, cow, horse, camel; see Dukes 1970). Furthermore, although both of our species of mustelids show similar behavior (they are excitable and fast moving), the weasel has a BMR two to three times higher than expected from the standard curve for mammals (Iverson 1972). This might result in a higher body temperature. In other orders of mammals a small species often has a high body temperature (as in the domestic rat and the domestic mouse). On the other hand, the least weasel and the golden hamster are about the same size and have a nearly identical and low body temperature (Table 4). Kliber (1975) takes the view that the body temperature of mammals seems to be nearly the same independent of body size, namely about 36° to 38°C. Morrison suggested, however, in a classic paper (Morrison and Ryser 1952) that some correlation with weight might eventually be found within selected homogeneous groups. If the mustelid family were to contribute to this pattern of information, the least weasel would have the higher temperature and the wolverine the lower body temperature; since our results are the reverse, it is essential to compare these results with the body temperatures of other mustelids as reported in the literature to see if the least weasel is an exception. It is difficult to compile body temperatures from the literature because some authors neglect to state how the temperatures were obtained. If clinical thermometers or thermistors are used rectally, the animals must first be accustomed to this and must stand quietly for the measurement, or else the core temperature rises rapidly. On one occasion

Kendeigh (1946) held a deermouse containing a rectal thermocouple; the body temperature increased over the starting value by 2.2°C in six minutes. Rarely are the measurements as reported in the literature resting body temperatures. The best method is to take temperatures at four times of the day; the lowest mean represents rest and the highest, activity. Many of the values in Table 4 were obtained in this fashion. In our search for mustelid temperatures, we could not use the values in Spector (1956) because no methods were given. We were able to find resting values of only three other mustelid species (Table 4). Brown and Lasiewski (1972) present an additional figure for the ermine (39.0°C) based upon "temperatures taken rectally with a thermistor at the end of the metabolic determinations." This could not be called a resting value; instead we calculated the regression line for their metabolism measurements at different air temperatures. Scholander et al. (1950) state that these measurements (called the thermal neutral profile, Folk 1974) extrapolate to resting body temperature. Thus we read off a calculated resting value of 38°C (Table 4).

The six mustelid species in Table 4 are arranged by size; there is no pattern in the resting body temperatures which range from 36.4° to 38°. Probably the suggested correlation between body temperature and size will not be found in the mustelidae.

The low body temperature of the least weasel is not uncommon in small hyperactive mammals. A cursory review of known resting values is presented; many of these are the

daily low values from measurements made four times a day. It was easier to find body temperatures between 36.0° and 37.8 (Class I), for small hyperactive mammals, than it was to find temperatures above 38.0 (Class II). The lemming and vole are examples of small mammals with a "high" body temperature

Body temperatures taken at four times of the day should give a clue to the behavior of the species being studied. Although our wolverines were in captivity, they were studied in a restricted area without disturbances, and they were certainly accustomed to the distant noises about them. They would not obey a zeitgaber of food since they were fed ad libidum and each stored its excess of reindeer meat in cool parts of the cage. An impression in the popular literature is that wolverines are frequently day-active (Murie 1963). We have four types of evidence to relate to this statement: 1) our direct observations during this experiment and also over a 10-year period at Barrow; 2) our previous publication on heart rates taken every 30 minutes all summer of three wolverines at Barrow; 3) the body temperature readings at the start of the present study taken every 30 minutes; and 4) the mean body temperatures at four times of the day reported in this study. This evidence is presented in Table 5. The three wolverines studied in 1963 are referred to as I, II, and III. Those in this paper are K, L, M, and N. The first group (I, II, III) were more prone to be active around midnight although this sometimes extended until noon; the second group was more active in the morning. Apparently this

species chooses day-activity at least part of the time.

The activity patterns of K, L, M, N were the same in winter and summer (although this is not illustrated), and the times of low body temperatures indicate that their activity patterns were in phase (since all low averages were at 6 AM).

The daily behavior of the weasels might also be determined from the body temperatures taken four times of the day. They also were fed ad libidum. Their lowest temperature (36.3°) came at noon and their highest (37.3°) at midnight. From this evidence we would call them nocturnal.

A final point is whether regular activity in the cage produced an excessive body temperature. Both the weasels and the wolverines at times showed hyperactivity; the wolverines especially, would run in circles and spontaneously fling themselves on the side of the cage, or leap in play to the top of the cage (2.5m). One would predict that this would induce a high body temperature; when all high values of body temperatures for each day were averaged, the least weasel showed a daily increase due to exercise of 1.8°C and the wolverines a mean increase of 0.95 but individual values averaging 2.0° (Table 6). In an earlier study we showed the increase in the hamster to be 2.1°C (Folk et al. 1961); the daily increase in the wolf Table 3) was 1.4°. We presume that this increase for both the least weasel and the wolverine indicate the body temperature which would be present when these animals are hunting prey on the tundra. The

moderate increase in the wolverines is an indication of successful and efficient dissipation of heat.

In summary, the wolverine, which has a resting body temperature comparable to that of the arctic wolf, appears to be a day-active species in that it becomes very active in the morning, with bouts of sleep during the night. A comparison of this animal's body temperature with that of the least weasel and with other mustelids shows no relationship between body temperature and size.

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CAPTION

Figure 1.

Abdominal body temperatures of two wolverines recorded by radio-capsule every hour. The sleep state of one animal is designated as S_1 and S_2.

Table 1.

LEAST WEASEL LIVER TEMPERATURES

(Quiet or Sleeping)(N = 13)

		Mean	Weight	Sex
6 AM	36.0°C		69.0g	F
	36.9		49.5	F
	37.6	36.8	52.2	F
Noon	36.5		41.0	M
	36.2	36.3	25.0	F
6 PM	38.1		41.0	F
	35.9		29.0	F
	37.6	37.2	69.6	M
Mid.	37.2		69.0	M
	37.6		35.0	F
	37.2	37.3	51.0	M
6 AM	37.0		29.0	F
	36.2	36.6	46.0	F
$\bar{X}$	36.9	36.8°C	46.6g	

TABLE 2.

WOLVERINE BODY TEMPERATURES

LOTTA ← (Winter 1975-1976)

DAY	6 AM	N	6 PM	M
1		38.7(H)	37.6	37.6
2	37.8	39.0(H)	38.1	(37.6)
6	(37.7)	38.4	38.9(H)	37.9
7	(37.3)	37.5	38.8(H)	38.2
8	37.8	(36.6)	38.8(H)	37.9
9	38.0	39.6(H)	38.9	(37.9)
10	(37.5)	38.1	38.5(H)	38.3
11	(37.7)	38.9(H)		
$\bar{X}$	37.69	38.23	38.51	37.91
SE	0.09	0.32	0.20	0.11

Table 3.

COMPARATIVE BODY TEMPERATURES OF FOUR SPECIES

	N	T_b at Mean LOWEST TIME			Mean of LOWEST DAILY T_b	
		Time	°C	SE	°C	SE
LEAST WEASEL	5	Noon	36.6	±.23	--	
HAMSTER	28	Noon	36.2	±.11	--	
ARCTIC WOLF (Winter)	9	Noon	37.9	---	--	
WOLVERINE K (Winter)	7	6 AM	36.3	±.17	36.3	±.17
L (Winter)	7	6 AM	37.7	±.09*	37.5	±.17**
M (Summer)	7	6 AM	38.0	±.11	37.8	±.08
N (Summer)	7	6 AM	38.4	±.26	38.2	±.27
	3		$\bar{X}$	38.0	$\bar{X}$	37.8

* Data for Wolverine L from Table 2, 6 AM column.

** Data for Wolverine L from Table 2, mean of temperatures that are in parentheses.

TABLE 4.

Resting Temperatures of Unexcited Mammals in Order of Weight

Mustelid Species

Species	N	Mean°C	Range or SE	Reference
Least Weasel	6	36.6	0.23	This paper
Ermine (Long Tail Weasel)	4	38.0*	---	Brown et al.'72
Mongoose	4	38.3	0.54	Baldwin et al.'52
Striped Skunk	3	36.4	0.14	Folk '57
Wolverine	4	38.0	0.25	This paper
Sea Otter	4	37.9	0.29	Morrison et al.'74
Other Mammals				
Class I: Low T_b				
Shrew sp.	--	37.8	36°-38°	Kleiber '75
Peromyscus maniculatus	8	36.1	0.53	Kendeigh '45
Blarina brevicauda	2	34.7	34.5-34.9	Kendeigh '45
Golden Hamster	15	36.2	0.11	Folk et al.'61
Golden Hamster	15	36.85	0.07	Jones et al.'76
Gerboa	8	36.8	0.05	Kirmiz '62
Tree Shrew	3	35.7	35.1-36.1	Whittow et al.'76
Porcupine	28	37.5	36.0-38.2	Irving et al.'54
Bearded Seal	5	37.2	36.8-37.3	Irving et al.'54
Class II: High T_b				
Redback Vole	6	38.3	0.87	Morrison et al.'54
Brown Lemming	9	38.0	0.13	Ferguson et al.'70
Arctic Fox	10	39.3	36.6-41.5	Irving et al.'54

* Calculated Value

TABLE 5.

Sleep (S) vs. Activity Peaks (AP)/Quarter Day of Seven Wolverines

Specimens	Method	8A-2P	2P-8P	8P-2A	2A-8A
I, II, III	Direct Observation	I	S	AP	I*
I, II, III	Heart Rate Reading (see Folk, 1964)	I	S	AP	AP
K, L, M, N	Direct Observation	AP	S	S	I
K, L, M, N	30 m. Readings (see Fig.1)	AP	S	S	I
K, L, M, N	Mean 8 Days	AP	AP	I	S

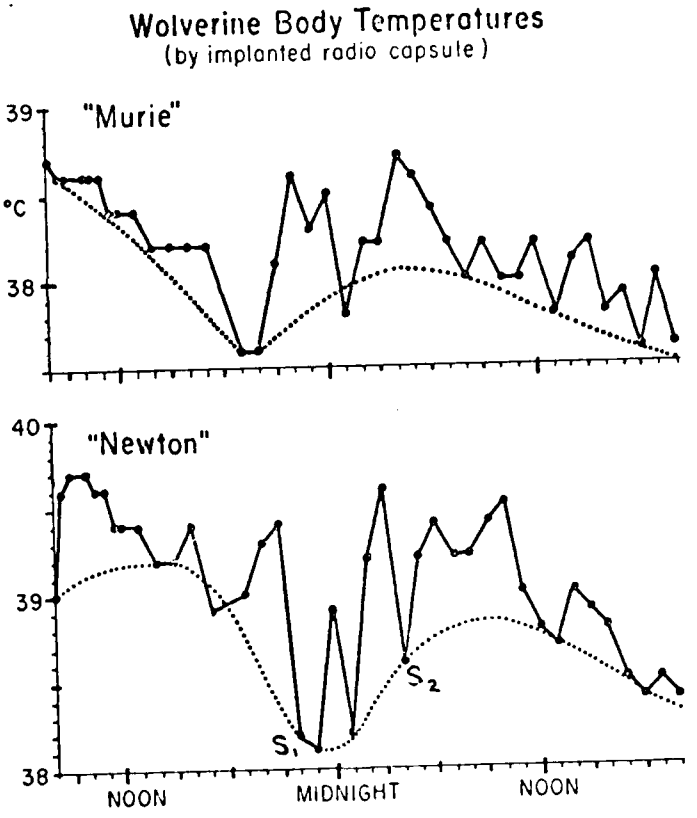
* "I" signifies mild activity or dozing. AP often included hyperactivity.

TABLE 6.

Daily Increase of Body Temperature Due to Exercise of Four Wolverines (°C)

	Lowest Mean (at 6AM)	Lowest Single Value	Highest Single Value	Range
K (winter)	36.3	36.2	37.8	1.6
L (winter)	37.7	37.3	39.6	2.3
M (summer)	38.0	37.5	38.8	1.3
N (summer)	38.4	36.8	39.4	2.6
			Mean	2.0

Fig 1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(by implanted radio capsule)
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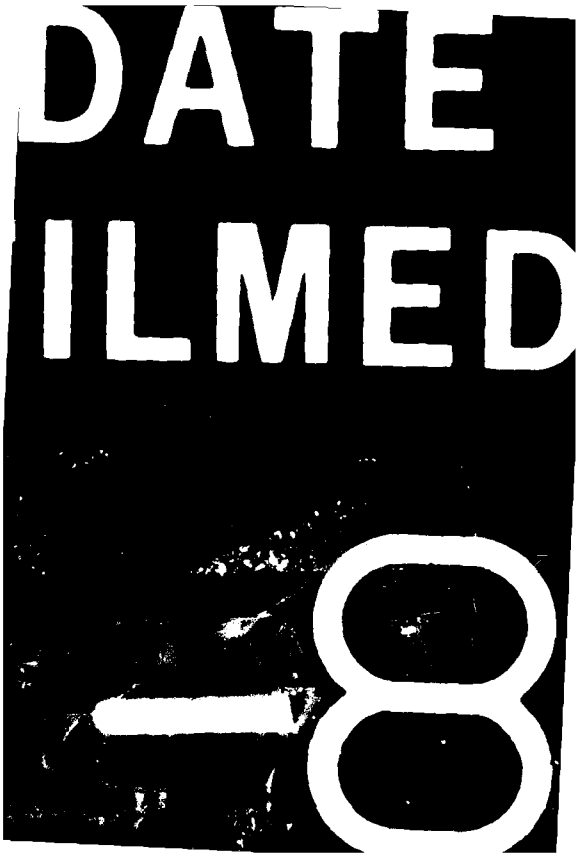
°C
38
"Newton"
40
39
38
S1
S2
NOON
MIDNIGHT
NOON

S1

S2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